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The Effect of Acute Normovolaemic Haemodilution on Blood Transfusion Requirements in Abdominal Aortic Aneurysm Repair

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Objective: *to evaluate the impact of acute normovolaemic haemodilution (ANH) on the blood transfusion requirements in elective abdominal aortic aneurysm (AAA) repair in a single vascular unit.*
Methods: *thirty-two patients underwent ANH during elective AAA repair between 1992 and 1997. The operation was performed by the same surgeon/anaesthetist team in 75% of cases. Their demographic details, type of aneurysm (infra-renal or supra-renal), preoperative blood cross match, use of intra-operative red cell salvage, blood loss, peri-operative bank blood requirements, pre-op and on-discharge haemoglobin levels and post-operative outcome were recorded. The results were compared to a group of 40 randomly selected patients (to represent the unit average) who underwent elective AAA repair by variable surgeon/anaesthetist teams without ANH in the same time period.*
Results: *there were more supra-renal AAA repairs in the ANH group (8/32) than in the non-ANH group (0/40, $p<0.01$). ANH patients required significantly less blood transfusion peri-operatively (median 2 units) than the non-ANH patients (median 3 units, $p=0.02$). There were no other significant differences between the variables measured.*
Conclusion: *these results suggest that a dedicated team can achieve significant reductions in the use of heterologous blood transfusion compared to the vascular unit average experience by the effective use of ANH.*

Key Words: Acute normovolaemic haemodilution; Autologous blood transfusion; Abdominal aortic aneurysm repair.

Introduction

Despite a high degree of safety offered by modern transfusion services, it becomes evident that the best blood transfusion is the patient's own (autologous) blood.[1] Heterologous blood transfusion carries a risk of rare but serious complications such as immediate haemolysis due to ABO incompatibility following clerical error, transfusion related acute lung injury, transmission of infective agents or bacterial contamination of red cells and platelets.[2,3]

Autologous blood from acute normovolaemic haemodilution (ANH) retains all the properties of fresh whole blood and its quality is therefore superior to that of stored packed red blood cells or other blood products.[4,5] Autologous blood can be the only transfusion option for those patients who refuse bank blood (e.g. Jehovah's witnesses). Heterologous blood transfusion has been linked to immune suppression and increased risk of infection.[6–9] Evidence is emerging that autologous blood transfusion – alone or its combination with other modalities – can reduce the incidence of postoperative infectious complications and improve clinical outcome.[7,8,10–16]

ANH has been proposed as a useful blood conservation method.[14,17,18] Despite numerous reports of substantial savings in a variety of surgical procedures,[19–23] its clinical effectiveness remains controversial.[24–26] We have noted on our own unit that different surgeons and anaesthetists have different attitudes and approaches to the use of ANH, and were concerned that variations in the use of the technique may contribute to the clinical uncertainty over its value in clinical practice.

This retrospective study aims to assess whether the use of ANH on a vascular unit by an experienced surgeon/anaesthetist team is effective in reducing the requirements for heterologous blood transfusion, compared to the unit as a whole.

Patients and Methods

Case notes and blood bank databases on all 32 patients who underwent ANH during AAA repair between 1992 and 1997 were reviewed. Results were compared to those from 40 randomly selected patients out of the 179 patients who underwent elective AAA repair without ANH on the vascular surgery unit at the

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Bristol Royal Infirmary during the same time period. During this time period, only one surgeon/anaesthetist team had a particular enthusiasm for ANH, and 24/32 (75%) ANH patients had AAA repair by this team. The 40 non-ANH patients were randomly selected from a combination of surgeon/anaesthetist teams to represent the unit experience as a whole. They were selected by random drawing of numbers from the list of AAA repairs created from a prospectively collected, computerised database of all vascular procedures performed on the unit.

Data was collected on demographic details, the type of AAA repair (infra- or supra-renal), the number of units of blood cross-matched pre-operatively, the amount of blood withdrawn as ANH, the intra-operative blood loss, the use of intra-operative red cell salvage, the number of units of heterologous blood transfused intra- and post-operatively, pre-operative and on-discharge levels of haemoglobin (Hb) and surgical complications.

Technique

ANH was performed on induction of anaesthesia. Blood was withdrawn via a central line into storage bags containing an anticoagulant solution (Baxter, U.K.). The amount removed was determined by the anaesthetist's experience and adjusted according to pre-operative Hb and cardiovascular status. Usually between 2 and 3 bags of blood were withdrawn. Normovolaemia was maintained by the infusion of the same volumes of either Gelofusin or 6% hydroxyethyl starch (HAES). The blood was kept in theatre at room temperature. The ANH blood was always transfused back into the patient at the end of the operation once haemostasis had been achieved, if it had not been needed before then.

Blood loss was measured as a total volume of blood aspirated by suction from the operative field plus blood loss from weighed swabs. Centrifugal cell salvage devices were used in patients from both groups.

No standardised transfusion trigger was used and the decision to transfuse heterologous, cross-matched blood depended on blood loss, cardiovascular reserve and intra-operative performance as well as the anaesthetist's experience. In the ANH group, cell salvaged blood was transfused initially, then the ANH blood, then heterologous blood in that order of preference.

Statistical methods

Means and parametric tests (Student's *t*-test) were used for comparison of normally distributed variables between the two groups. Populations of variables, which were not normally distributed, were expressed by medians (ranges) and non-parametric tests were used for comparative analysis (Mann–Whitney). Chi-square tests were used for proportions. *P* value of 0.05 and less was considered as statistically significant.

Results

Demographics

The ANH group comprised 7 female and 25 male patients with a mean age (range) of 72 (51–87) years and the control group, 12 female and 28 male patients with a mean age (range) of 74 (59–86) years (not significant, Student's *t*-test). There were 8 suprarenal and 24 infra-renal AAA repairs in the ANH group, while all AAA repairs in the control group were infra-renal, the difference being significant ($p = 0.009$, chi-square test).

Blood loss and transfusion

Patients in the ANH group had a median (range) of 4 (2–10) units of bank blood cross-matched pre-operatively compared to 6 (2–10) units in the control group which was statistically significant ($p = 0.004$, Mann–Whitney). Patients in the haemodilution group had a mean volume (range) of 700 ml (450–1200 ml) withdrawn as ANH. Patients in the ANH group lost a median (range) of 1550 ml (250–8350 ml) of blood intra-operatively compared to 1800 ml (400–11 000 ml) in the non-ANH group (not significant, Mann–Whitney).

In the ANH group, cell salvage was used in addition to ANH in 10 patients (31%) with a median (range) volume of 700 ml (150–1600 ml) of red cell concentrate. In the non-ANH group cell salvage was used in 20 patients (50%) with a median (range) volume of 900 ml (200–2500 ml) of red cell concentrate salvaged and retransfused (not significant, Mann–Whitney).

Patients who had ANH were transfused peri-operatively (intra- and post-operatively) a median (range) of 2 (0–7) units of heterologous blood compared to 3 (0–22) units in the control patients, achieving statistical significance ($p = 0.016$, Mann–Whitney). The mean pre-operative and on-discharge Hb levels in the ANH patients were 13.8 g/dL and 11.5 g/dL respectively, compared to 13.4 g/dL and 11.1 g/dL in the control group (not significant, Student's *t*-test).

Clinical outcome

In the ANH group 9 (28%) patients suffered postoperative complications but there were no peri-operative deaths. In the control group 18 (45%) patients developed postoperative complications and 4 of them subsequently died (not significant, chi-square test). There were no obvious differences in the type of complications between the two groups (respiratory 5 ANH vs 6 non-ANH, cardiac 3 ANH vs 7 non-ANH, renal 2 ANH vs 0 non-ANH, other 4 ANH vs 7 non-ANH).

Discussion

In contrast to autologous predonation or cell salvage, ANH incurs no major costs as the equipment in the form of collection bags and infusion sets is simple and inexpensive and no trained operator is required to collect the blood. Considerable anaesthetic expertise is required to use ANH effectively, as intra-operative drops in blood pressure are managed more by pharmacological manipulation and the infusion of non-blood products and cell salvage blood than by the use of bank blood. Transient intra-operative Hb levels as low as 6 g/dL can occur and post-operative transfusion triggers of 8 g/dL are difficult to enforce in a population of medical attendants trained to transfuse when the Hb falls below 10 g/dL.

This study suggests that ANH can present a valuable addition to intra-operative red cell salvage, which is already known to reduce bank blood requirements in major surgical procedures.[27] Autologous predonation is another alternative, but suffers the disadvantages inherent in blood storage such as loss of oxygen carrying capacity, loss of clotting ability and risk of bacterial contamination.

The study also suggests that a dedicated and experienced surgeon/anaesthetist team within a vascular unit can achieve significant savings in heterologous blood usage compared to the unit experience as a whole by using ANH. Statistical analysis of other variables revealed no significant differences between the two groups in terms of age, sex, intra-operative blood loss, use of cell salvage, pre-operative and on-discharge Hb levels or post-operative outcomes. There was a significant difference in the proportion of suprarenal AAA repairs between the two groups due to the interest of the surgeon involved, with more suprarenal repairs in the ANH group. This effect might be expected to act to the disadvantage of the ANH group as such repairs are often associated with major blood losses. Despite this factor, significantly less heterologous blood was transfused in the ANH group.

This study was not a randomised, controlled trial and may contain other operator-dependant bias. Although the non-ANH group was randomly selected out of all the AAA repairs performed by variable teams to represent the unit average experience, the majority of the ANH group represents the experience of a single surgeon/anaesthetist team. Confidence in their use of ANH is reflected in significantly fewer units of blood being requested pre-operatively. It may also have led to less use of bank blood post-operatively by the application of lower transfusion triggers in that particular team, even though there was no difference in haemoglobin levels from non-ANH patients on hospital discharge.

The study suggests that a dedicated surgeon/anaesthetist team can achieve reductions in the use of heterologous blood by using ANH with other blood conservation methods compared to the unit average. In order to eliminate operator dependant bias, the effectiveness of ANH should be tested in a prospective, randomised, controlled study. Our experience to date suggests that participants in such a trial need to be fully trained and enthusiastic in the use of ANH if they are to achieve significant savings in bank blood use.

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